Construction of MODIS-like IR Absorption Radiances from VIIRS based on VIIRS-CrIS Fusion: Impact on Cloud Property Retrievals

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Improve decadal continuity of cloud products

Construction of IR bands based on imager-sounder data fusion

Compare measured to constructed (fusion) radiances (MODIS + AIRS)

Show global results for VIIRS+CrIS fusion

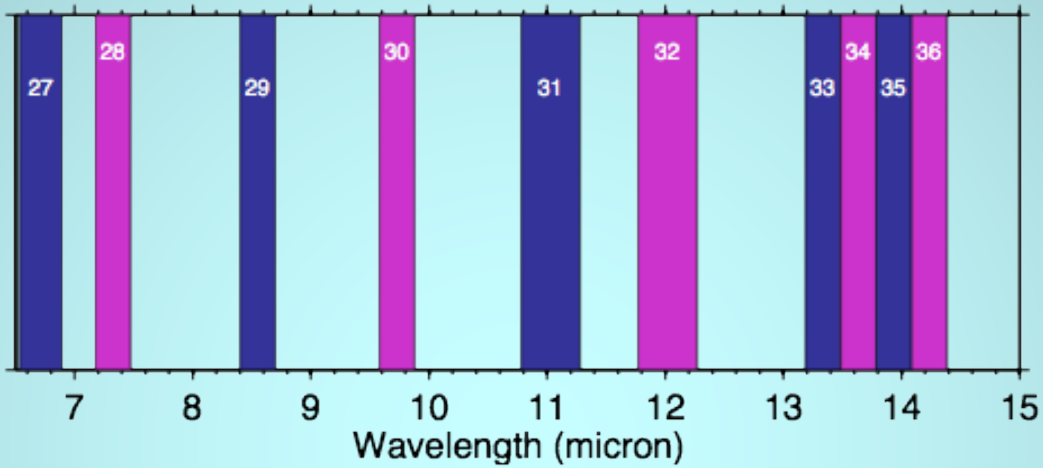
Initial results for CLAVR-x/ACHA and comparison with CALIPSO

Construction of broadband radiances at VIIRS M-band resolution

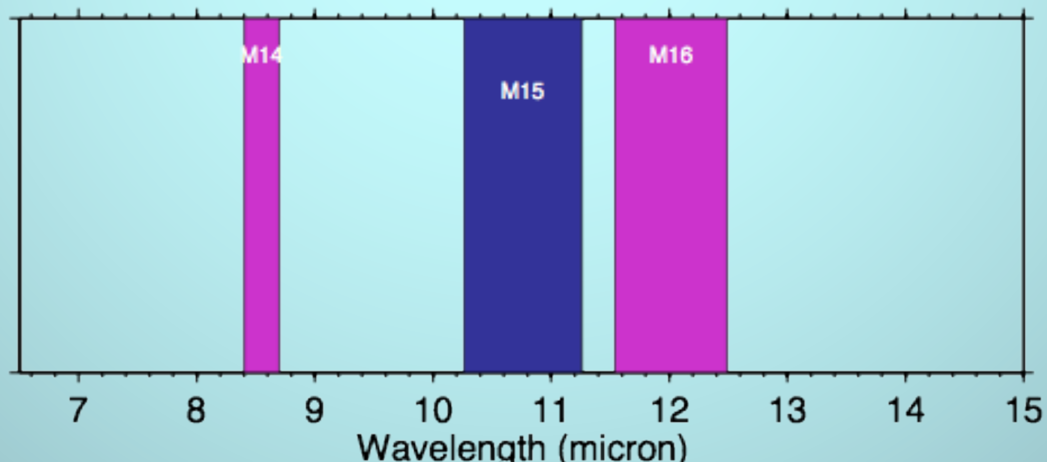
CERES Science Team Meeting
May 2019

VIIRS and MODIS IR spectral bands

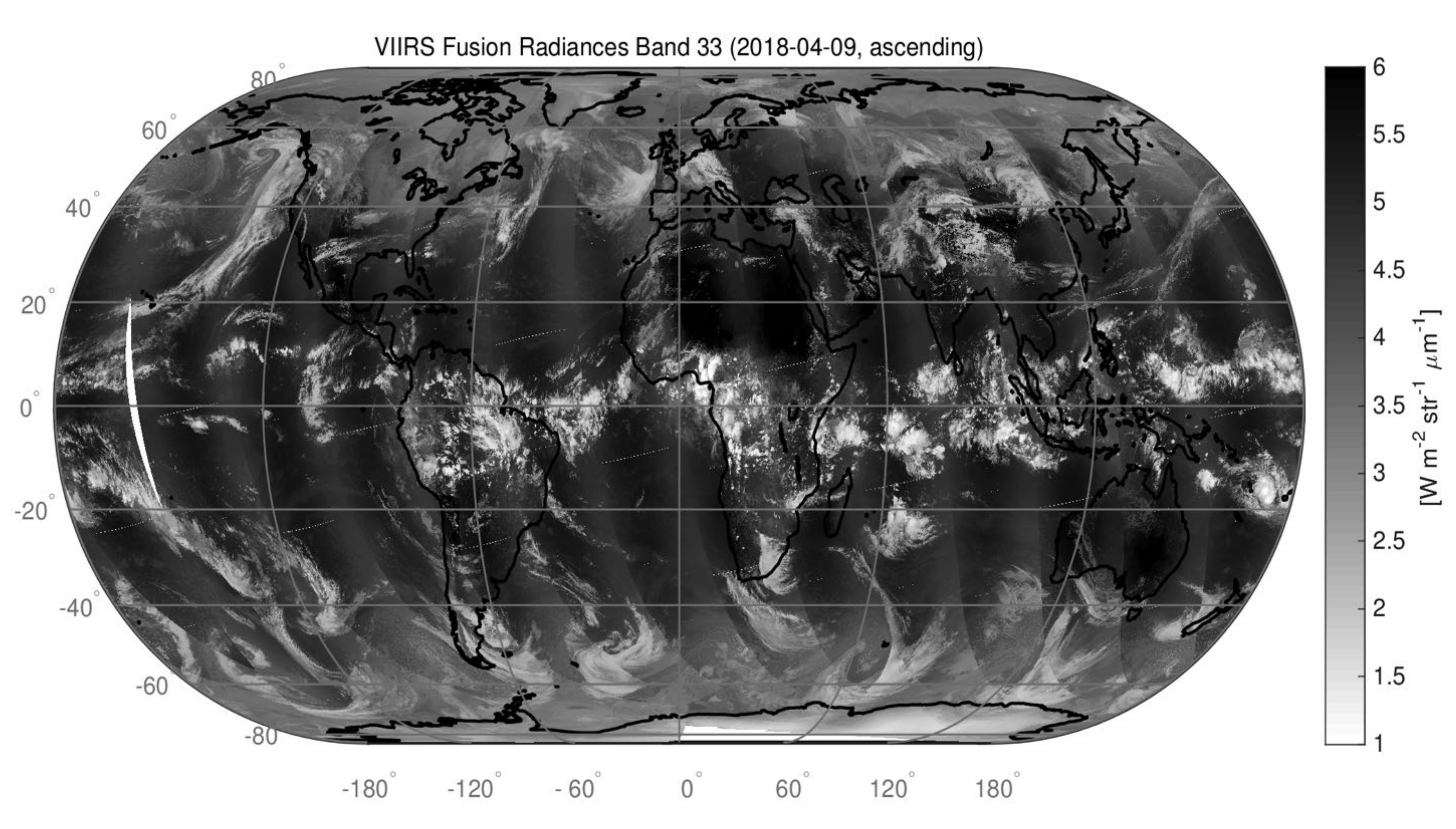
MODIS



VIIRS: M bands



VIIRS/CrIS Fusion Radiances for 13.3-μm Channel



Statistical Reconstruction

Step 1: Based on a relationship (*k*-d tree) between split-window imager pixel radiances (single pixel and average of pixels within a sounder FOV), find *N* sounder FOVs that best match a given pixel

Step 2: For each of the *N* sounder FOVs assigned to a given pixel, apply a set of spectral response functions (SRFs) to the hyperspectral radiances and calculate narrowband radiances

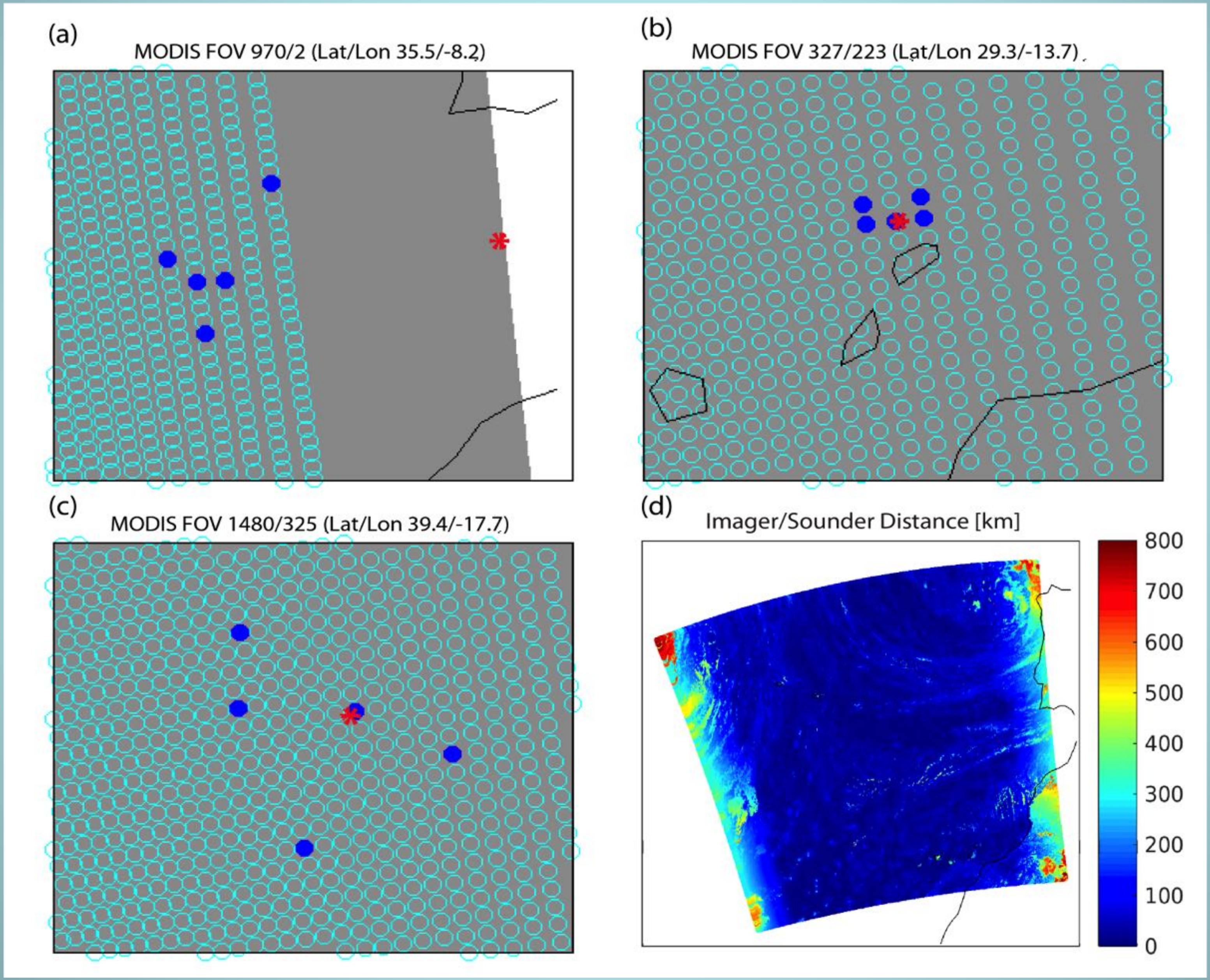
Step 3: Average the *N* narrowband radiances for each SRF and stamp on the pixel

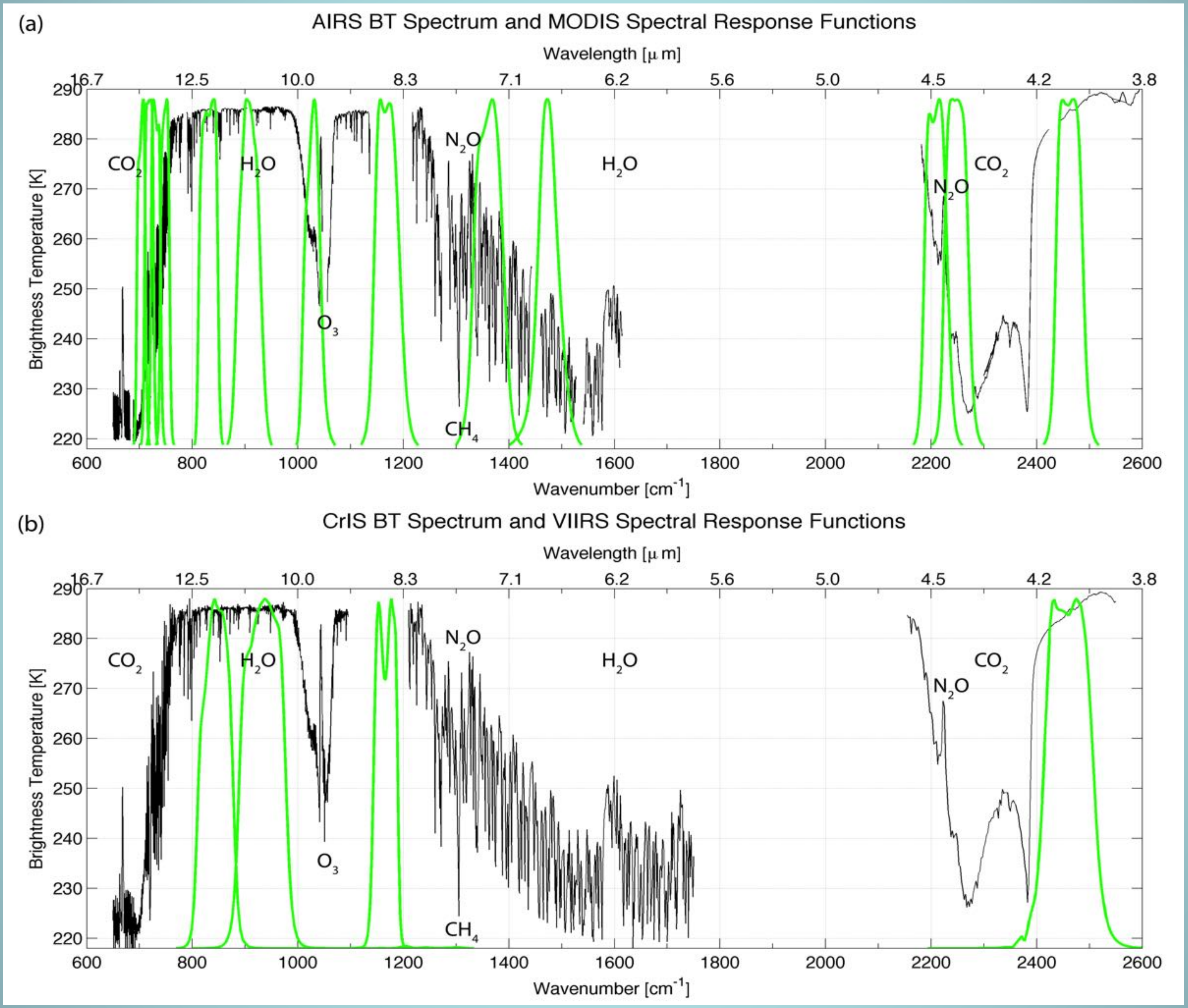
Cross et al., 2013: Statistical estimation of a 13.3-μm Visible Infrared Imaging Radiometer Suite channel using multisensor data fusion. *J. Appl. Remote Sens*. **7** (1), 073473, doi: 10.1117/1.JRS.7.073473.

Weisz, E., B. A. Baum, and W. P. Menzel, 2017: Fusion of satellite-based imager and sounder data to construct supplementary high spatial resolution narrowband IR radiances. *J. Appl. Remote Sens*. **11** (3), 036022, doi: 10.1117/1.JRS.11.036022

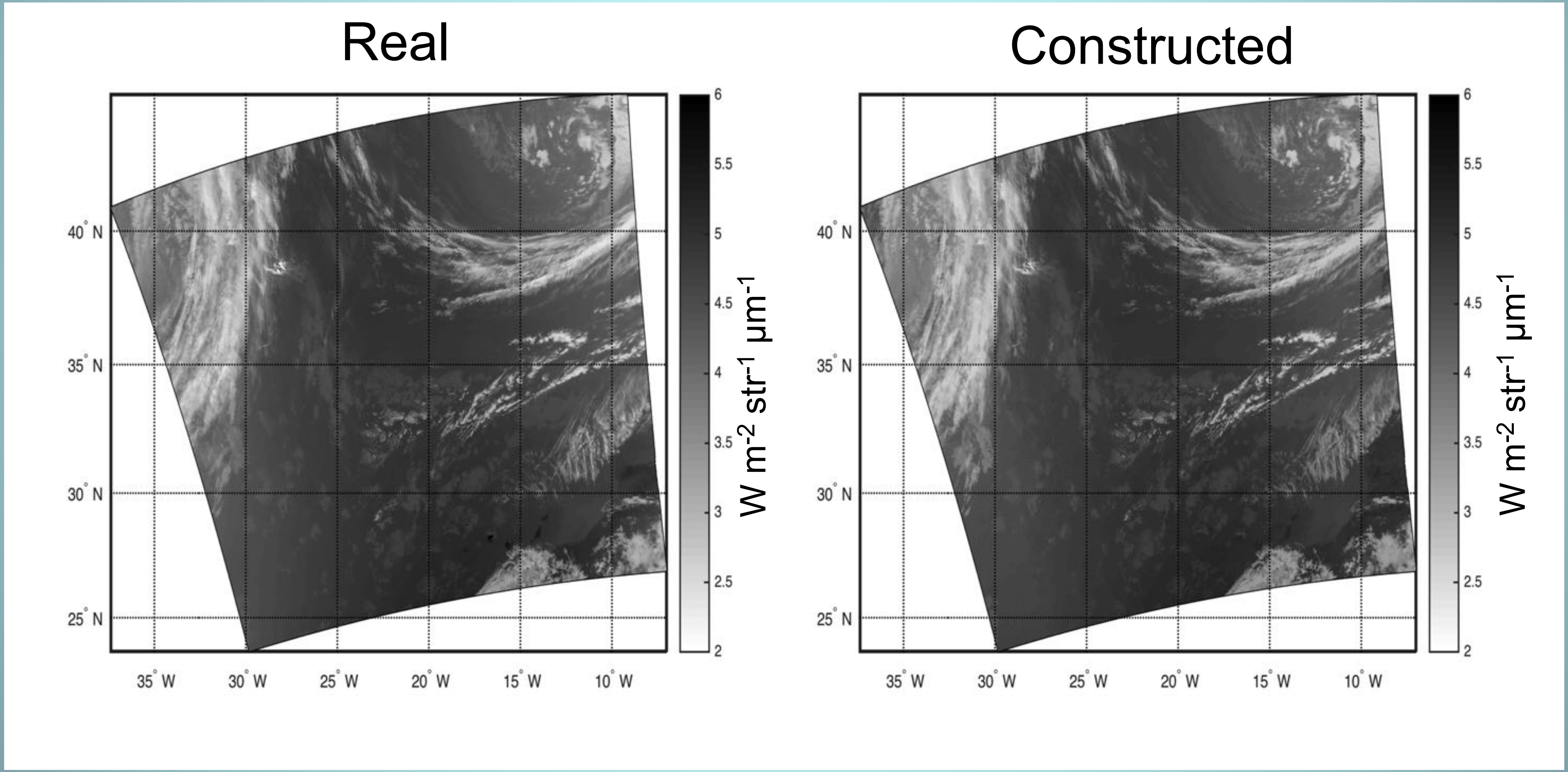
Collocation of *N* FOVs for a given imager pixel

Sounder FOV Selected imager pixel. Selected sounder FOV



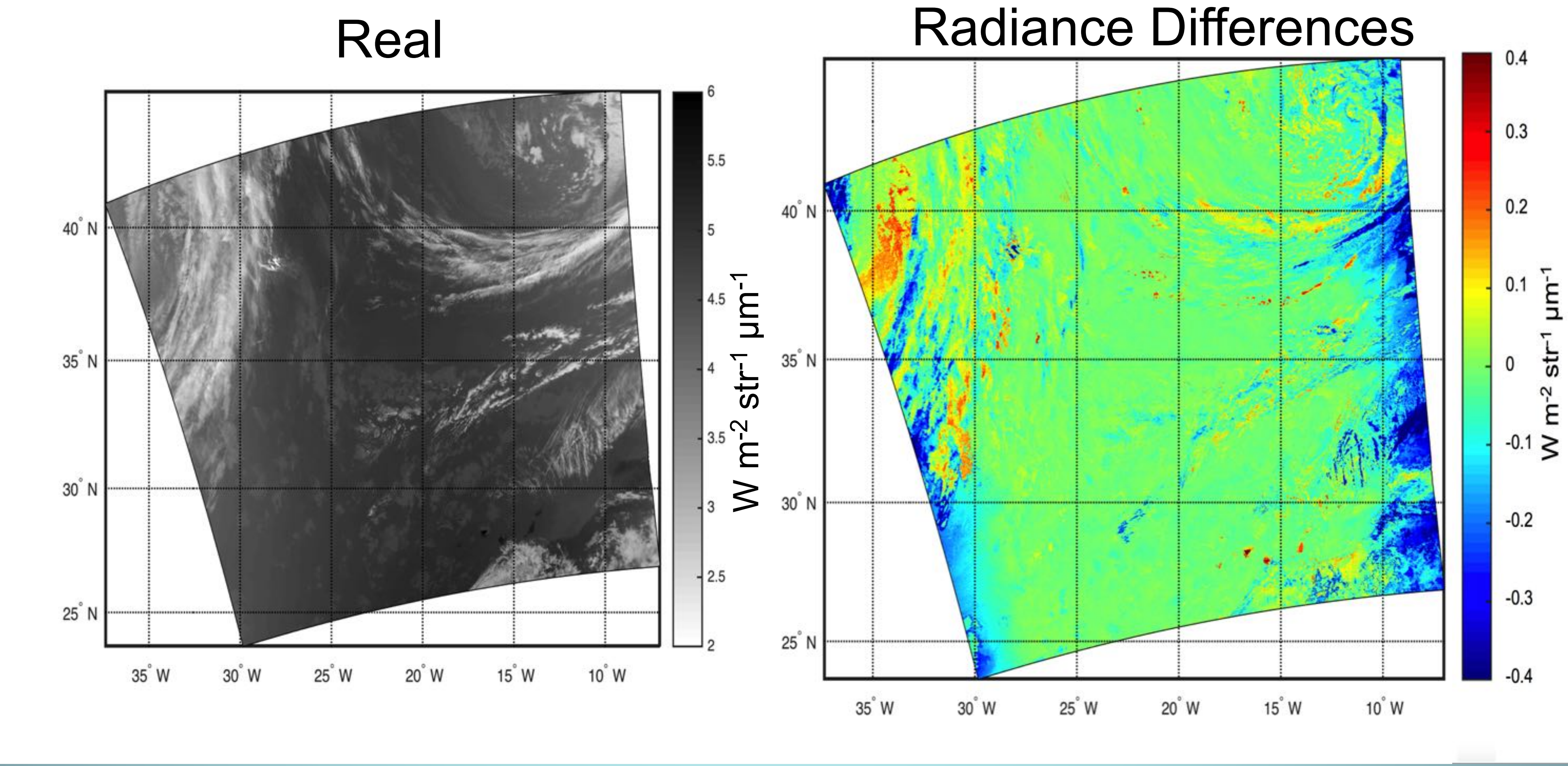

(a)
AIRS BT Spectrum and MODIS Spectral Response Functions
Wavelength [μ m]
16.7 12.5 10.0 8.3 7.1 6.2 5.6 5.0 4.5 4.2 3.8
Brightness Temperature [K]
290 280 270 260 250 240 230 220
CO_2
H_2O
N_2O
O_3
CH_4
H_2O
N_2O
CO_2
600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600
Wavenumber [cm^{-1}]
(b)
CrIS BT Spectrum and VIIRS Spectral Response Functions
Wavelength [μ m]
16.7 12.5 10.0 8.3 7.1 6.2 5.6 5.0 4.5 4.2 3.8
Brightness Temperature [K]
290 280 270 260 250 240 230 220
CO_2
H_2O
N_2O
O_3
CH_4
H_2O
N_2O
CO_2
600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600
Wavenumber [cm^{-1}]

Statistical construction of a high spatial resolution 13.3-μm MODIS channel from AIRS



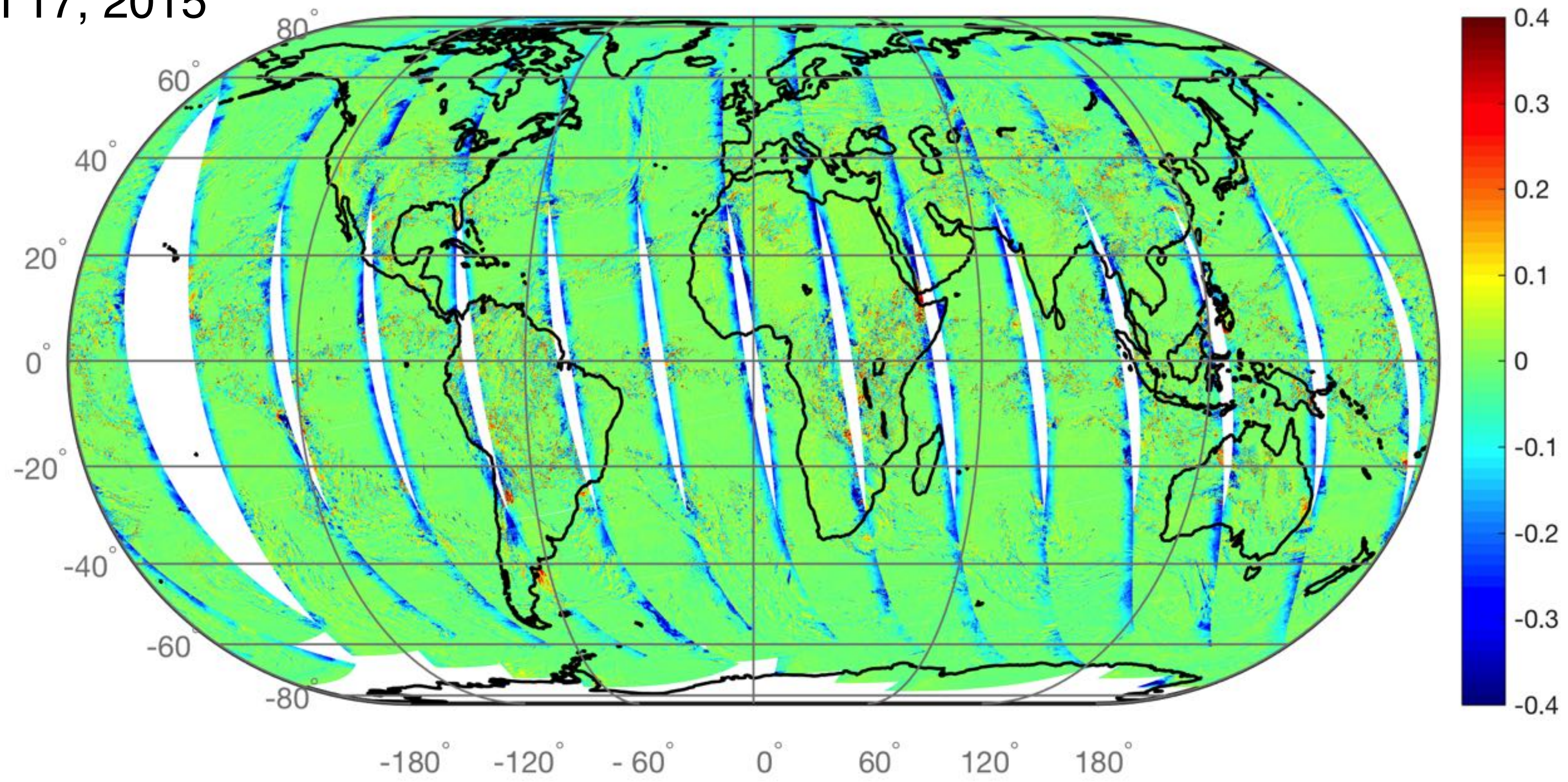
Scene over eastern Atlantic Ocean on April 17, 2015 at 1435 UTC

Radiance Differences Between Real and Constructed 13.3-μm channel



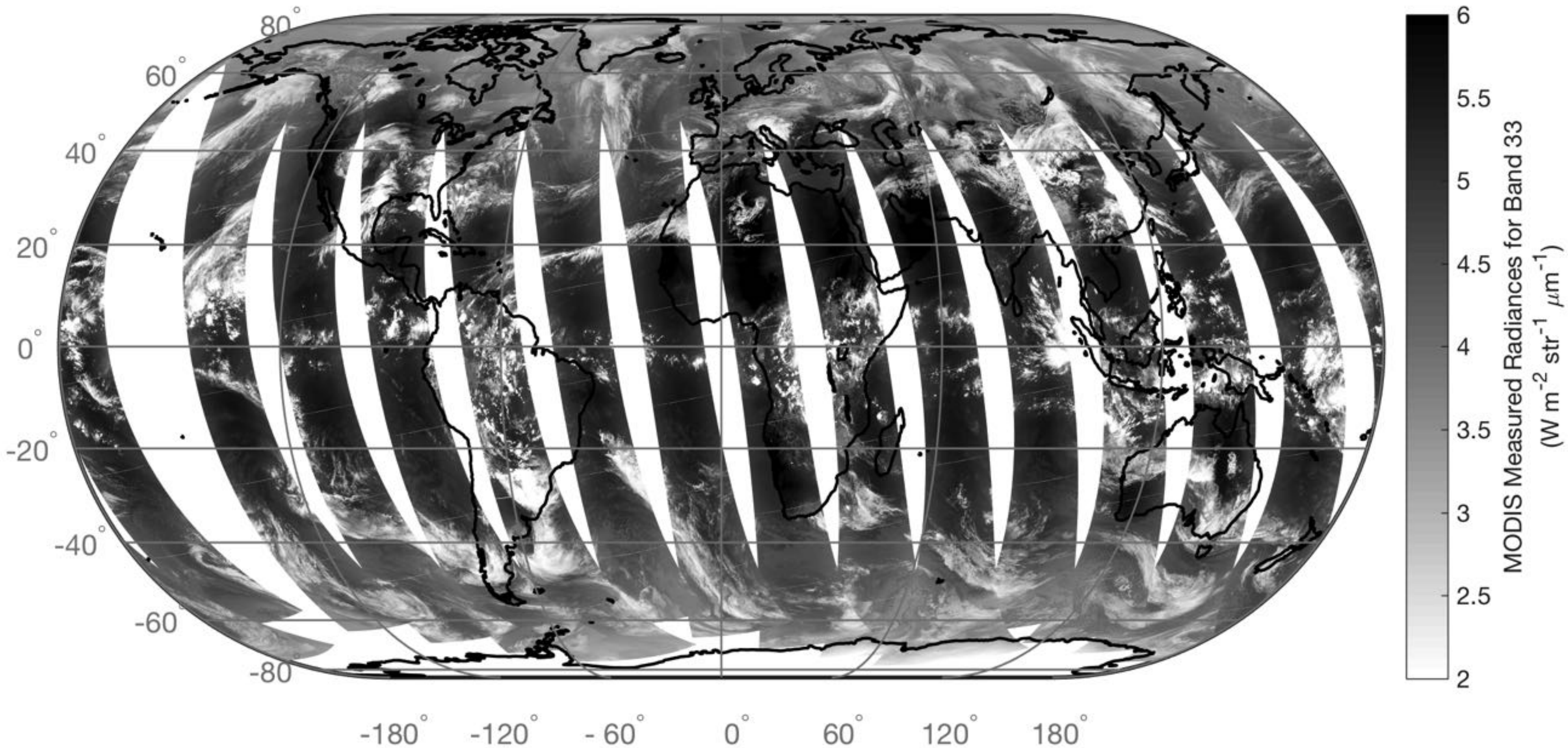
Full day of Radiance Differences Between Real and Constructed (Fusion) 13.3-μm channel MODIS+AIRS

April 17, 2015



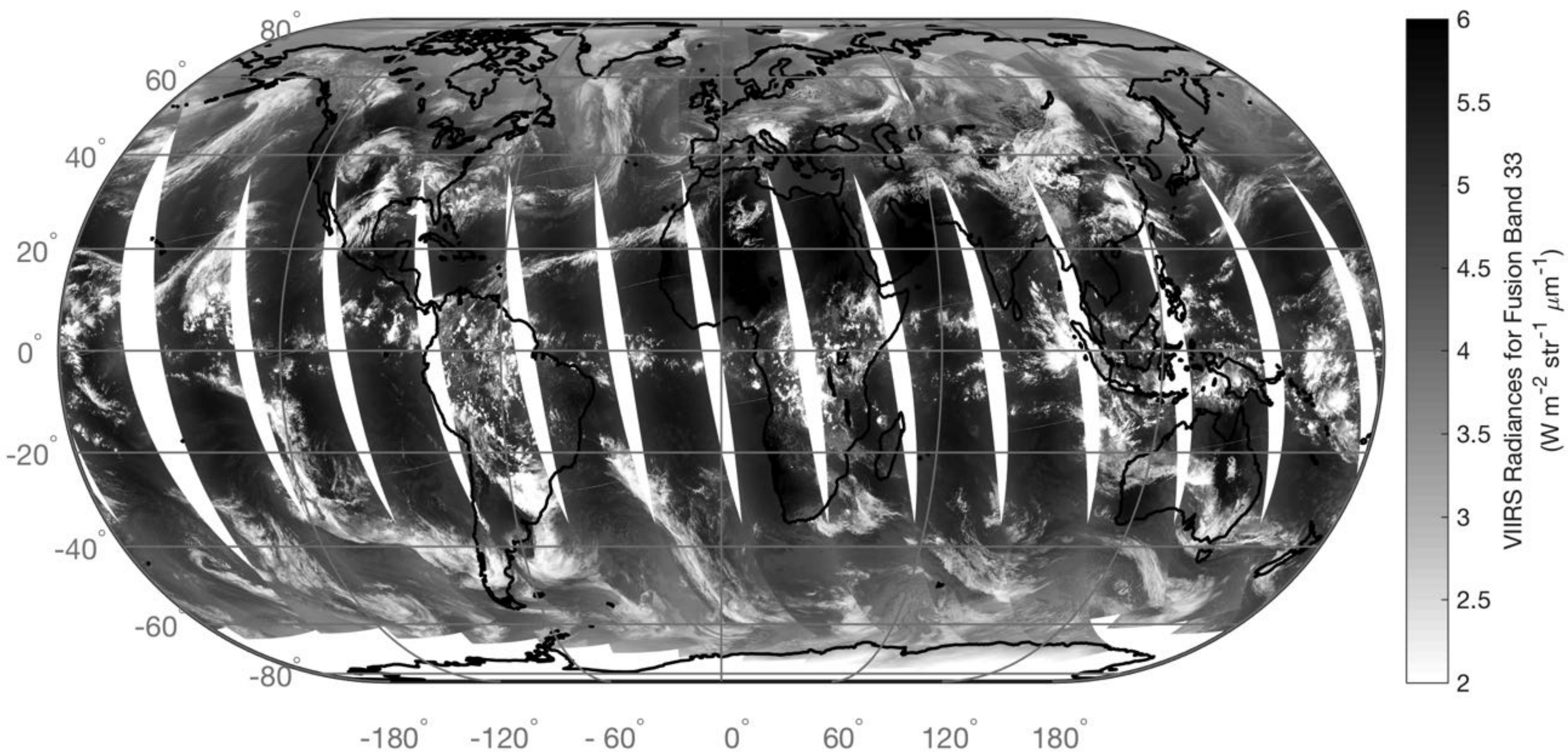
There is no adjustment for atmospheric absorption outside the range of the sounder swath (high scan angles). Results are best within the CrIS swath and degrade modestly outside of it.

Daytime MODIS measured 13.3-μm band radiances
Sensor zenith angle ≤ 57°
17 April, 2015



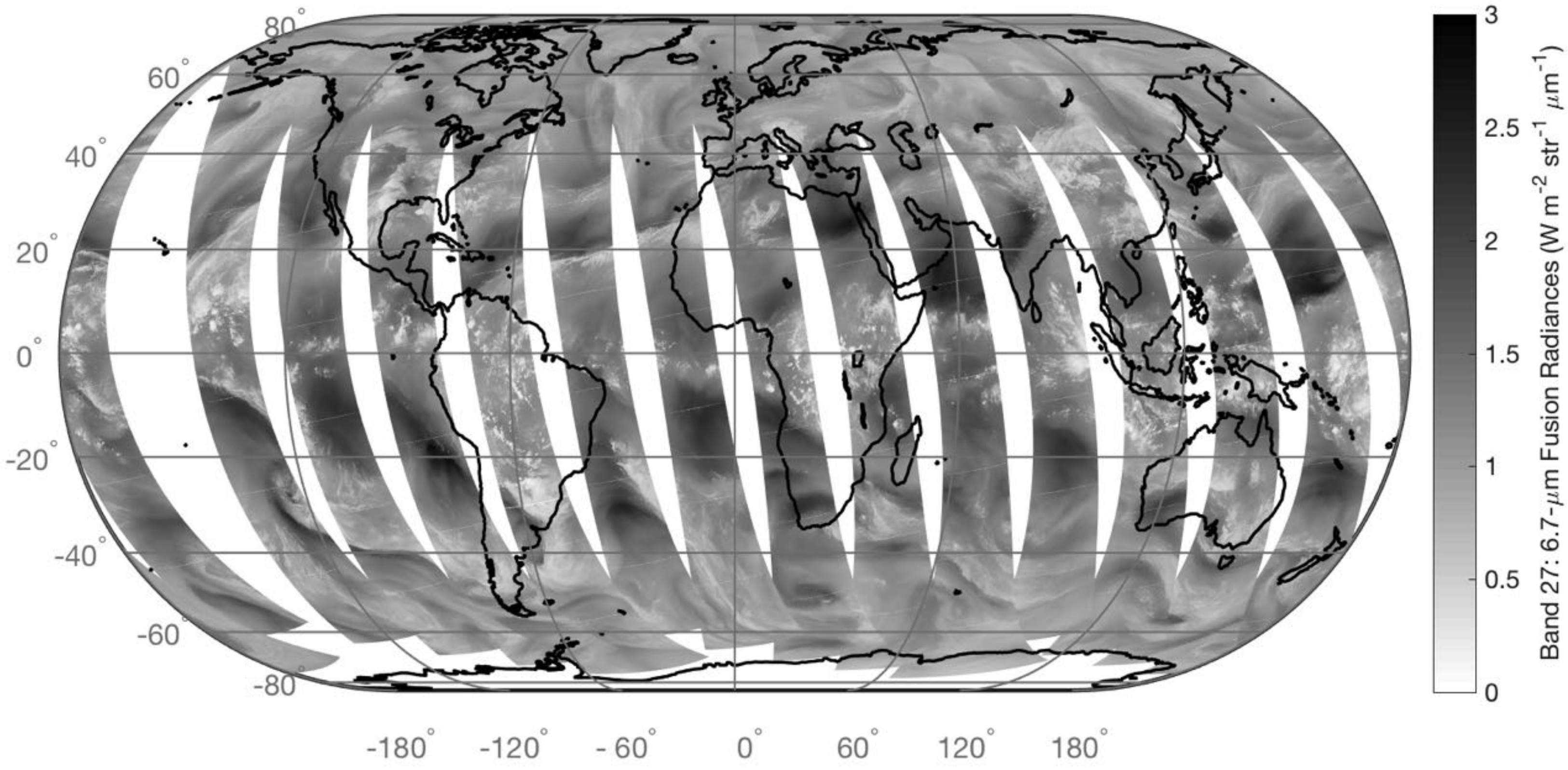
April 17, 2015

Daytime VIIRS-CrIS fusion 13.3-μm band radiances
No MODIS data used; only the relevant SRF
Sensor zenith angle ≤ 60˚



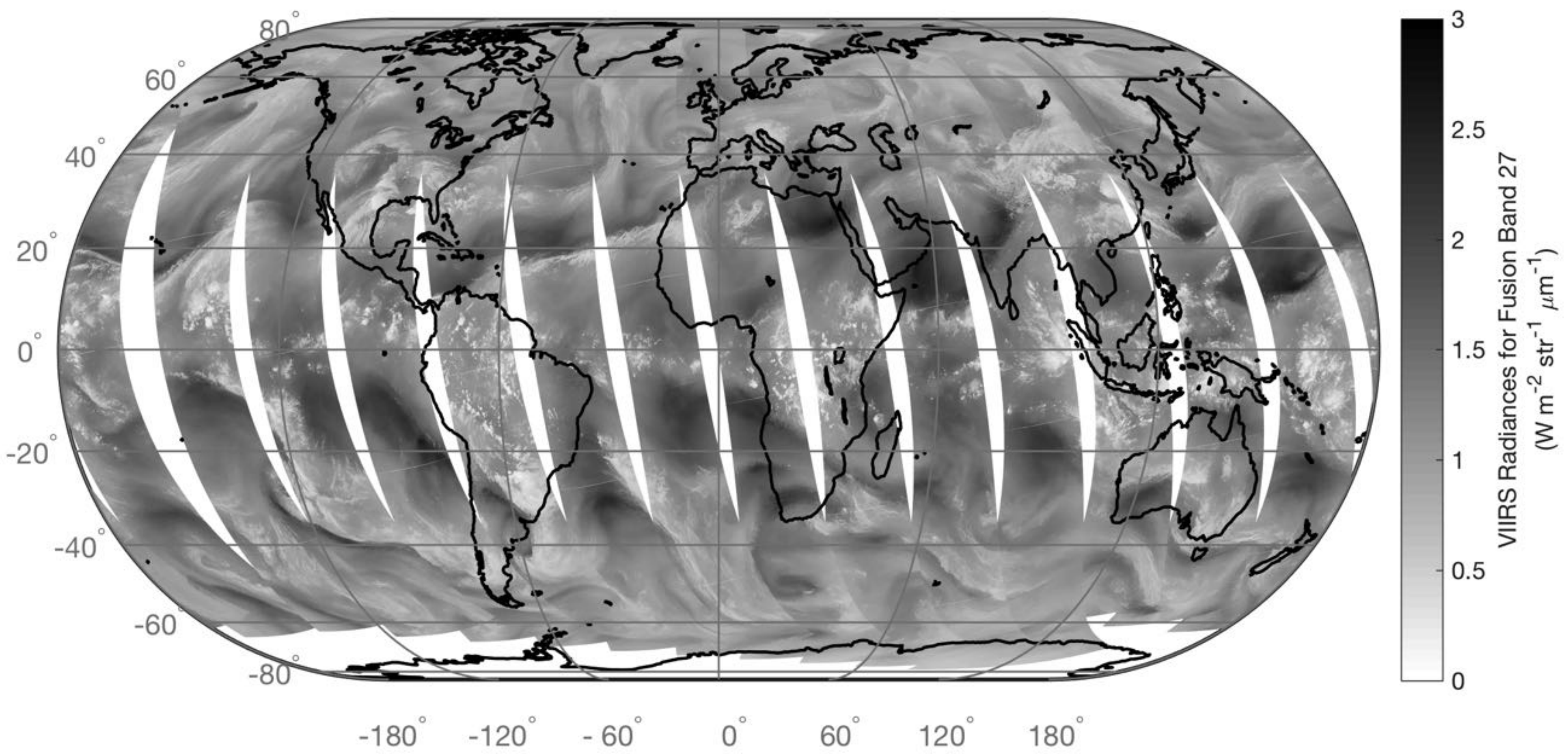
April 17, 2015

Daytime MODIS measured 6.7-μm band radiances
Sensor zenith angle ≤ 57°



April 17, 2015

Daytime VIIRS-CrIS fusion 6.7-μm band radiances
No MODIS data used; only the relevant SRF
Sensor zenith angle ≤ 60°



April 17, 2015

About the statistical construction approach

Pros:

- No detector striping, out-of-band response, or other artifacts
- Spectral response functions same as for MODIS-Aqua, i.e., they are known
- In fact, you can apply any response functions to construct new bands including those where lines of strong trace gas absorption are omitted
- Hyperspectral IR data are well calibrated
- Can apply MODIS retrieval algorithms to any platform with minor changes
- Can extend beyond the sounder swath but need to account for increased water vapor (and trace gas) absorption

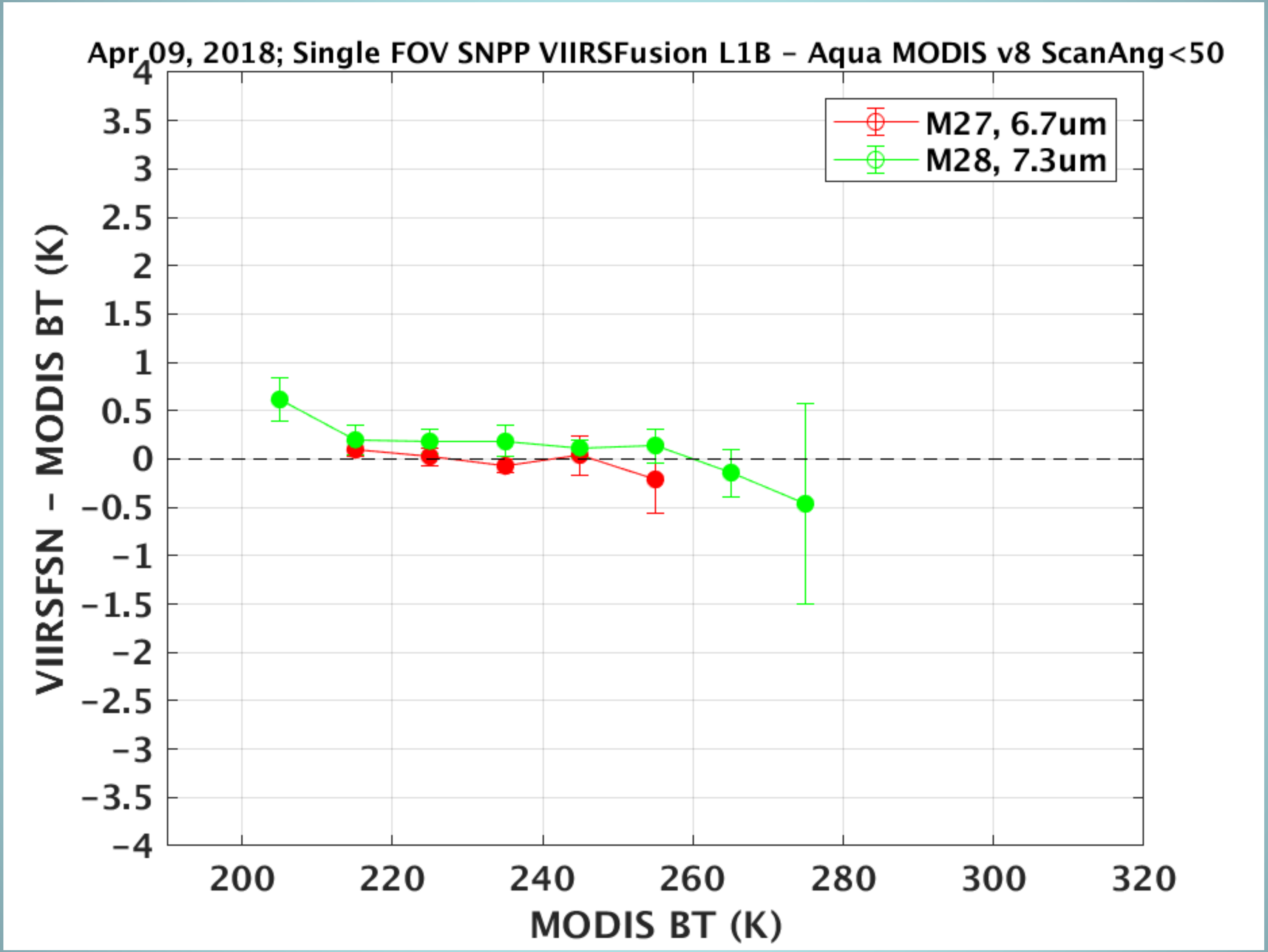
Cons:

- Radiance differences increase outside of sounder swath
- Increase in noise around edges of rapidly changing radiance fields
- May have more noise than an algorithm requires for accuracy
- Suspect that surface emissivity might be playing a small role in clear-sky conditions

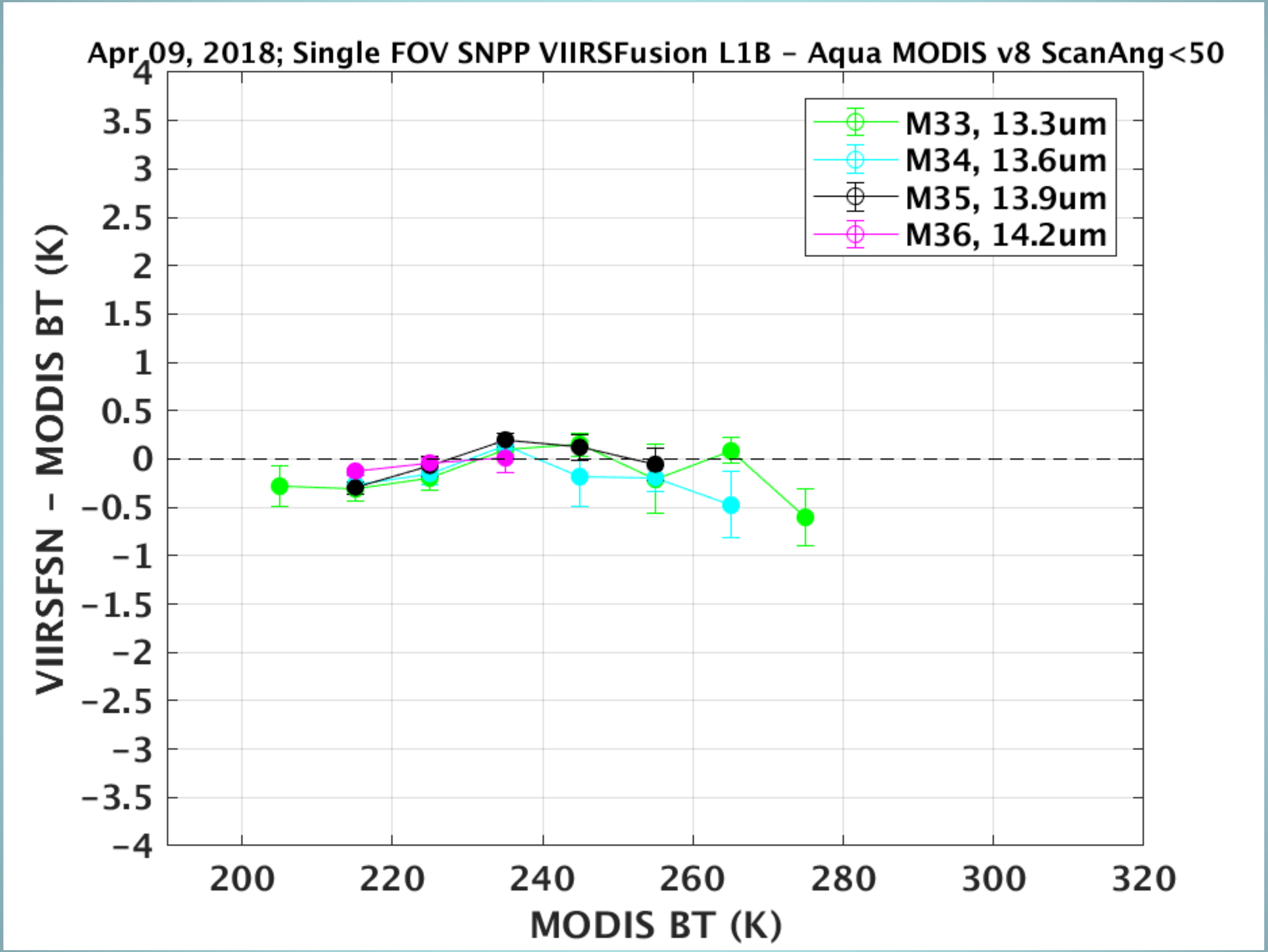
Radiance differences are about 0.5-2% of the total (~1-3K/typical scene)

VIIRS Fusion and Aqua MODIS Matchups April 09, 2018

- Global matchups abundant on this day
- Analysis limited to matchups where only one VIIRS measurement falls within the MODIS pixel field-of-view.
- Matchups filtered using cloud mask (99% confident clear only).
- Matchups include day+night, all surfaces



Apr 09, 2018; Single FOV SNPP VIIRSFusion L1B - Aqua MODIS v8 ScanAng<50
M27, 6.7um
M28, 7.3um
VIIRSFSN - MODIS BT (K)
MODIS BT (K)
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
200
220
240
260
280
300
320


Apr 09, 2018; Single FOV SNPP VIIRSFusion L1B - Aqua MODIS v8 ScanAng<50
M33, 13.3um
M34, 13.6um
M35, 13.9um
M36, 14.2um
VIIRSFSN - MODIS BT (K)
MODIS BT (K)
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
200
220
240
260
280
300
320

Impact on ice cloud height retrievals

Andy Heidinger (NOAA) and Yue Li (SSEC)

Study underway using PATMOS-x

In particular, results are from ACHA (AWG Cloud Height Algorithm; AWG refers to the NOAA Algorithm Working Group)

ACHA adopts an optimal estimation approach

Assessment relies on comparisons with CALIPSO

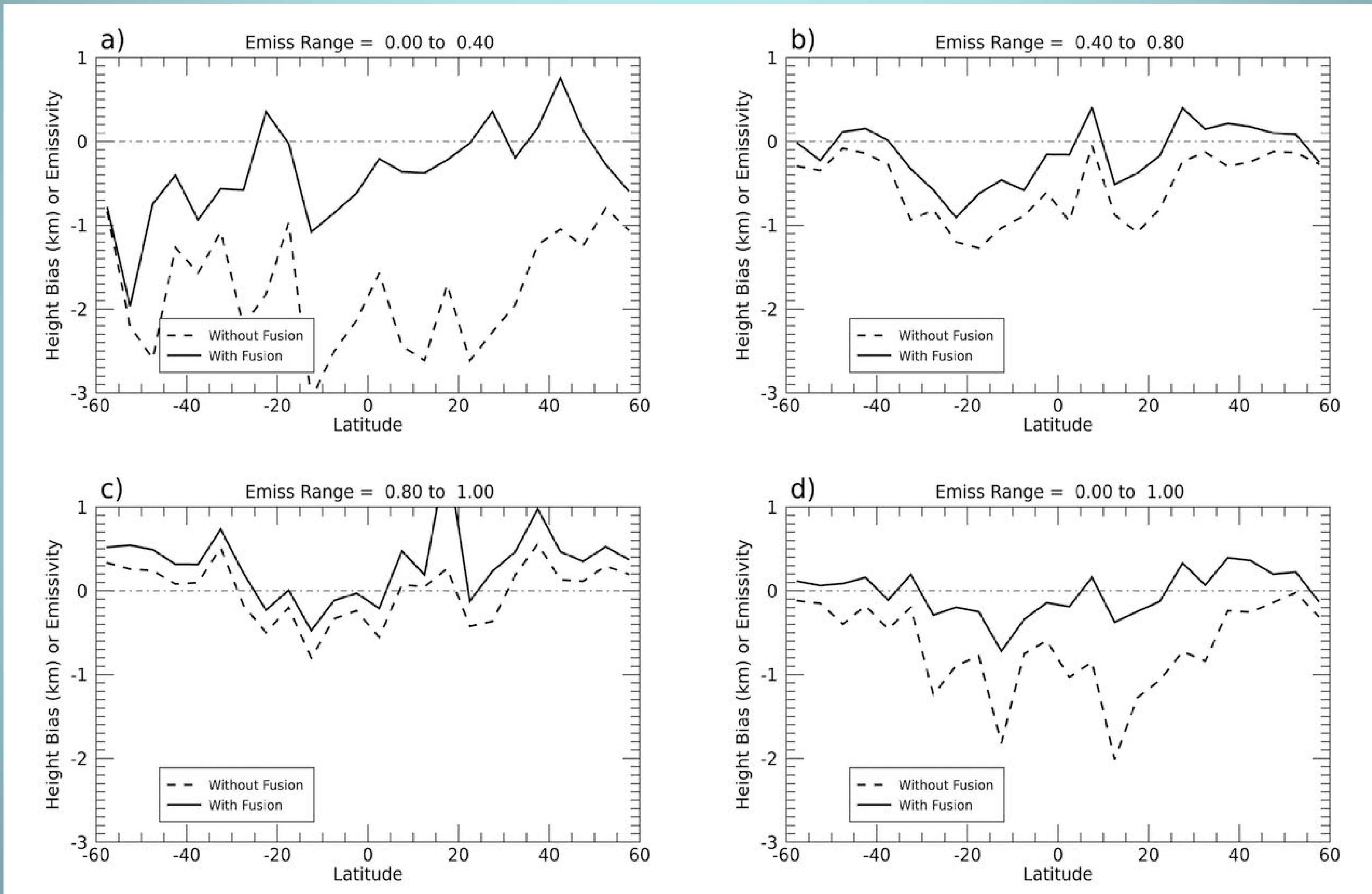
ACHA ice cloud comparison with CALIPSO

- One day for S-NPP (4/9/2018) & one day for NOAA-20 (1/3/2019)
- Collocations assume time difference < 15 minutes and lat/lon difference is < 4°
- CALIOP top layer cloud height is taken as truth, but adjusted in the way that if a cloud base height is available, the average of top and base is considered as truth height.
- Cloud type/phase from both VIIRS and CALIOP, number of cloud layers from CALIOP, and **emissivity computed using CALIOP COT** were used as additional filtering variables
- ACHA is run with **8.5, 11, 12μm (without fusion)** and **11, 12, 13.3μm (with fusion)**
- Each run produces different cloud mask, phase/type and cloud height products (all products from CLAVR-x).
- CALIOP data are a combination of V3.4 1km and 5km products, by adding 1km data to 5km data when clouds are not reported in the 5km product

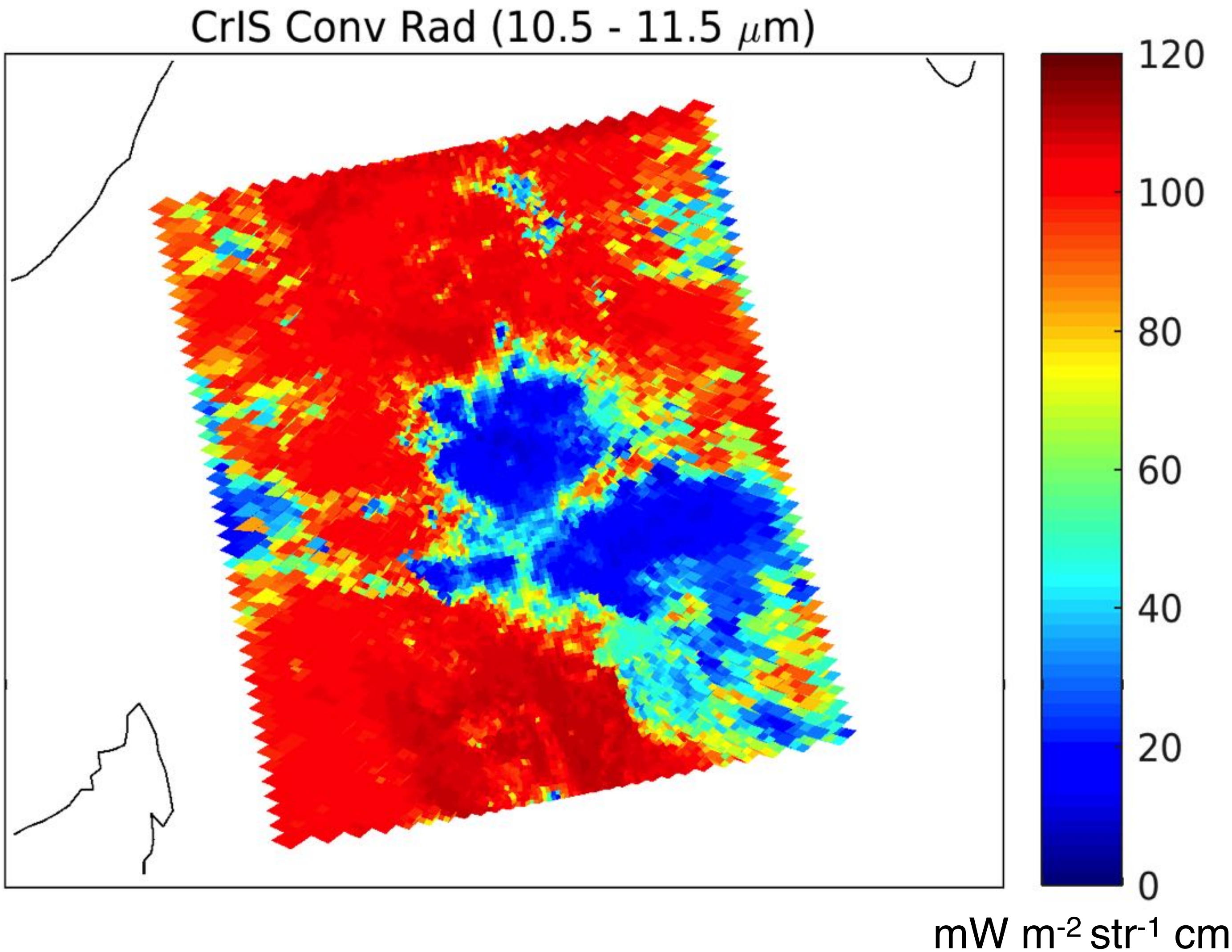
Suomi-NPP ACHA – CALIPSO comparisons

Emissivity		Counts	Bias (km)	Std dev (km)	Mode (km)
0 to 0.4	No fusion	7922	-1.92	3.62	-0.75
	With fusion		-0.39	1.47	-0.25
0.4 to 0.8	No fusion	16802	-0.45	1.44	-0.25
	With fusion		-0.06	0.94	-0.25
0.8 to 1	No fusion	16004	-0.06	1.03	-0.25
	With fusion		0.21	0.94	0.25
0 to 1	No fusion	40728	-0.58	2.07	-0.25
	With fusion		-0.02	1.09	-0.25

Zonal averages of CTH differences (VIIRS-CALIOP) between 60˚N and 60˚S for Suomi-NPP

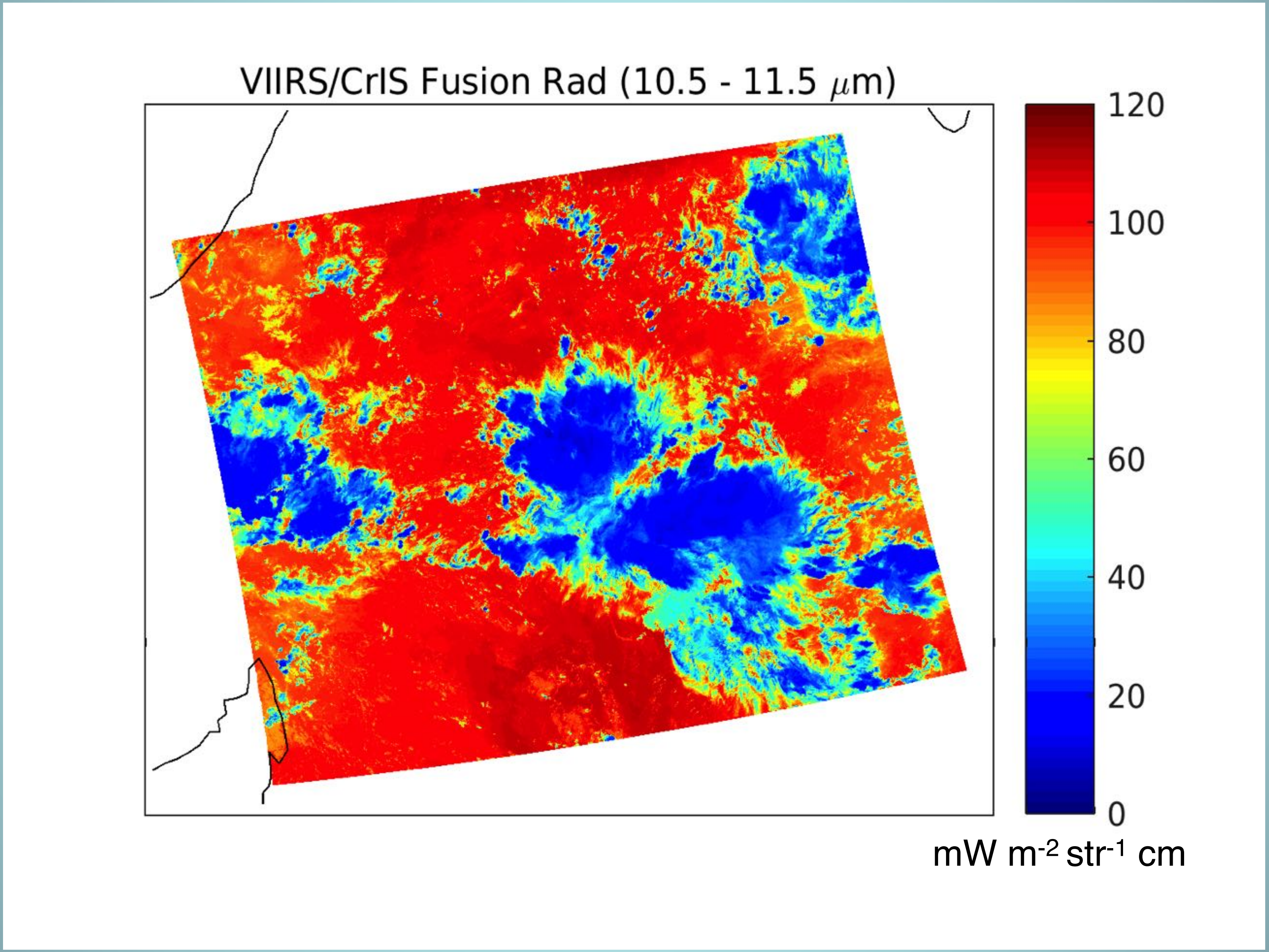


Construction of Broadband Radiances

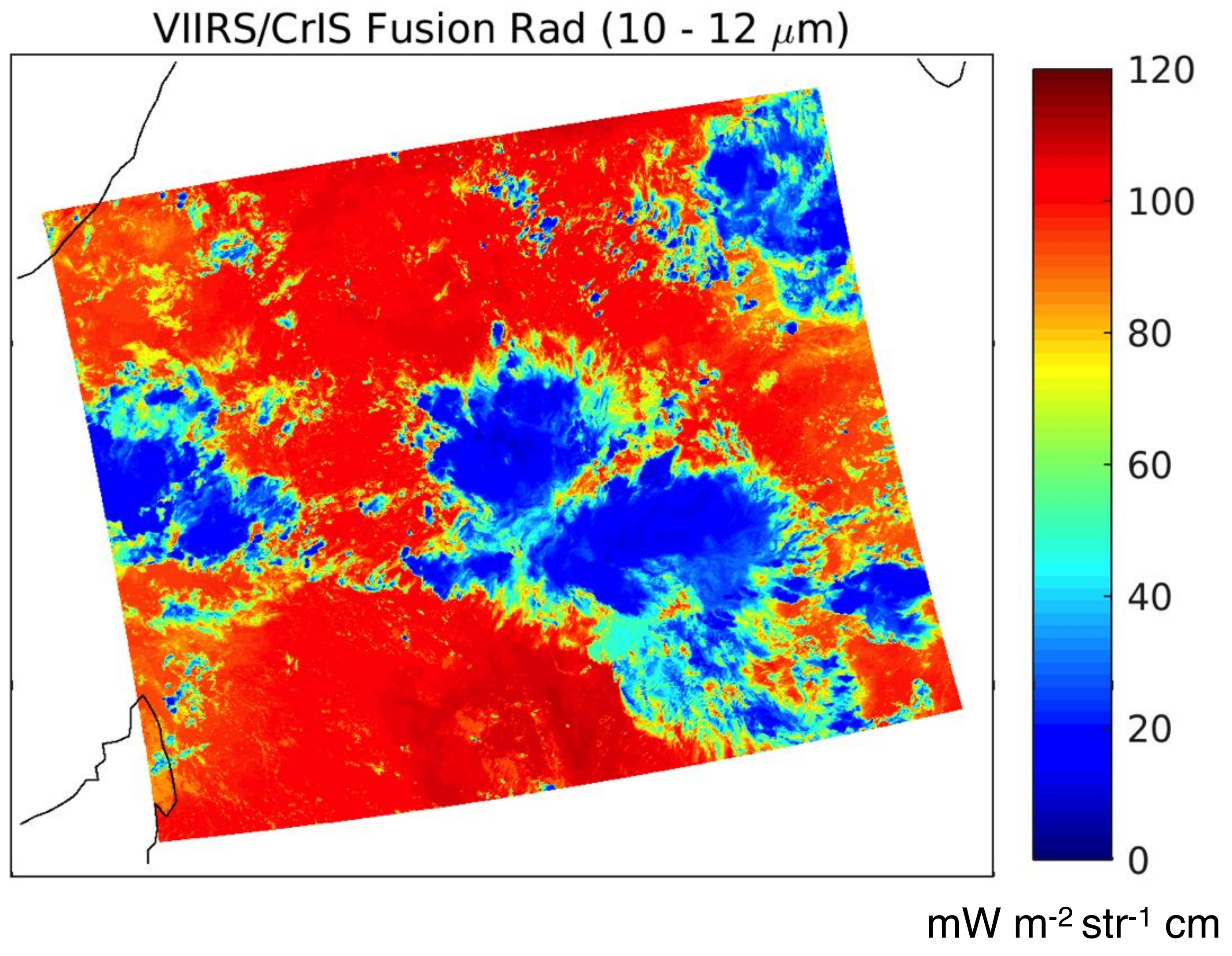


Indian Ocean; 9 April 2018

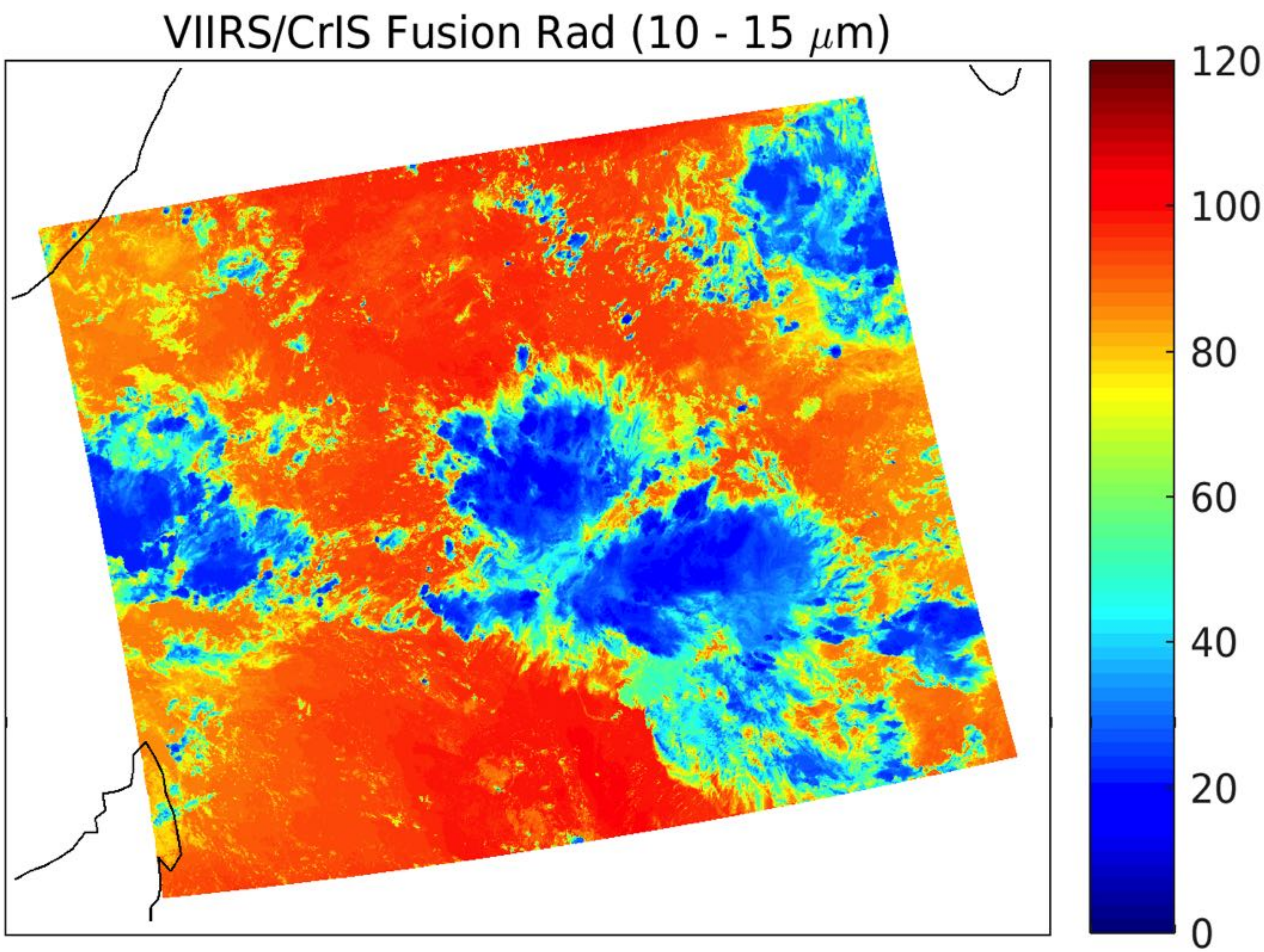
MODIS Band 31



Broadband Window at 750m resolution

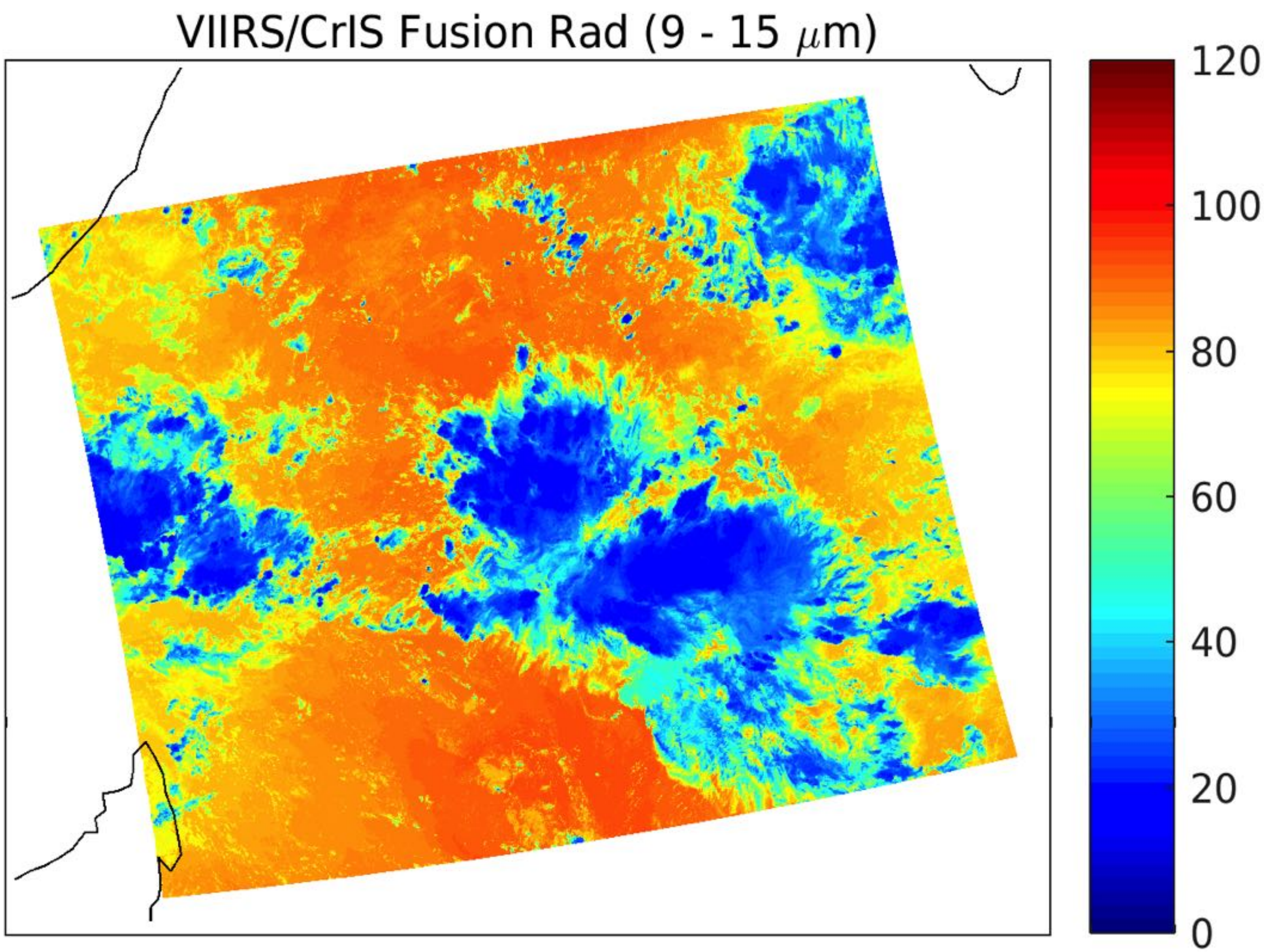


Broadband radiances: Adding CO_2 band



mW m^{-2} str^{-1} cm

Broadband Radiances: Adding O_3 band



$mW\ m^{-2}\ str^{-1}\ cm$

Availability of the VIIRS-CrIS fusion product

The VIIRS-CrIS fusion product is available at the Atmosphere SIPS; the record begins 01 January 2018 and is produced in forward stream for Suomi-NPP and beginning on 01 January 2019 for NOAA-20.

http://stc-se.com/data/bbaum/Baum-DataFusion/

The relevant Aqua MODIS-like IR radiance channels (MODIS channels 23-25, 27, 28, 30, 33-36) are added to the VIIRS Level 1b granule (NetCDF4).

Additionally, fusion channel radiances and brightness temperature differences are included for VIIRS M15 and M16 so a user can gain a sense of fusion-based construction errors.

The format is changing as we move closer to LAADS delivery.

Global ascending/descending browse imagery for 6.7- and 13.3-μm channels is provided for each day.

To date, fusion process runs successfully for ~98-99% of granules (a handful of days account for most of the failures)

Summary

Goal is to provide decadal continuity in cloud products (among others) across very different polar-orbiting imagers

Demonstrated ability to construct IR absorption band radiances for imagers based on imager-sounder data fusion (VIIRS+CrIS)

Achieve an order of magnitude increase in spatial resolution from sounder to imager at a cost of about 1% increase in noise

Capability to construct new channels at high spatial resolution, e.g., more water vapor channels or broadband radiances

Ability to construct radiances for any defined response function, perhaps with lines of strong trace gas absorption eliminated (would make forward modeling much faster)

Project: http://stc-se.com/data/bbaum/Baum-DataFusion/

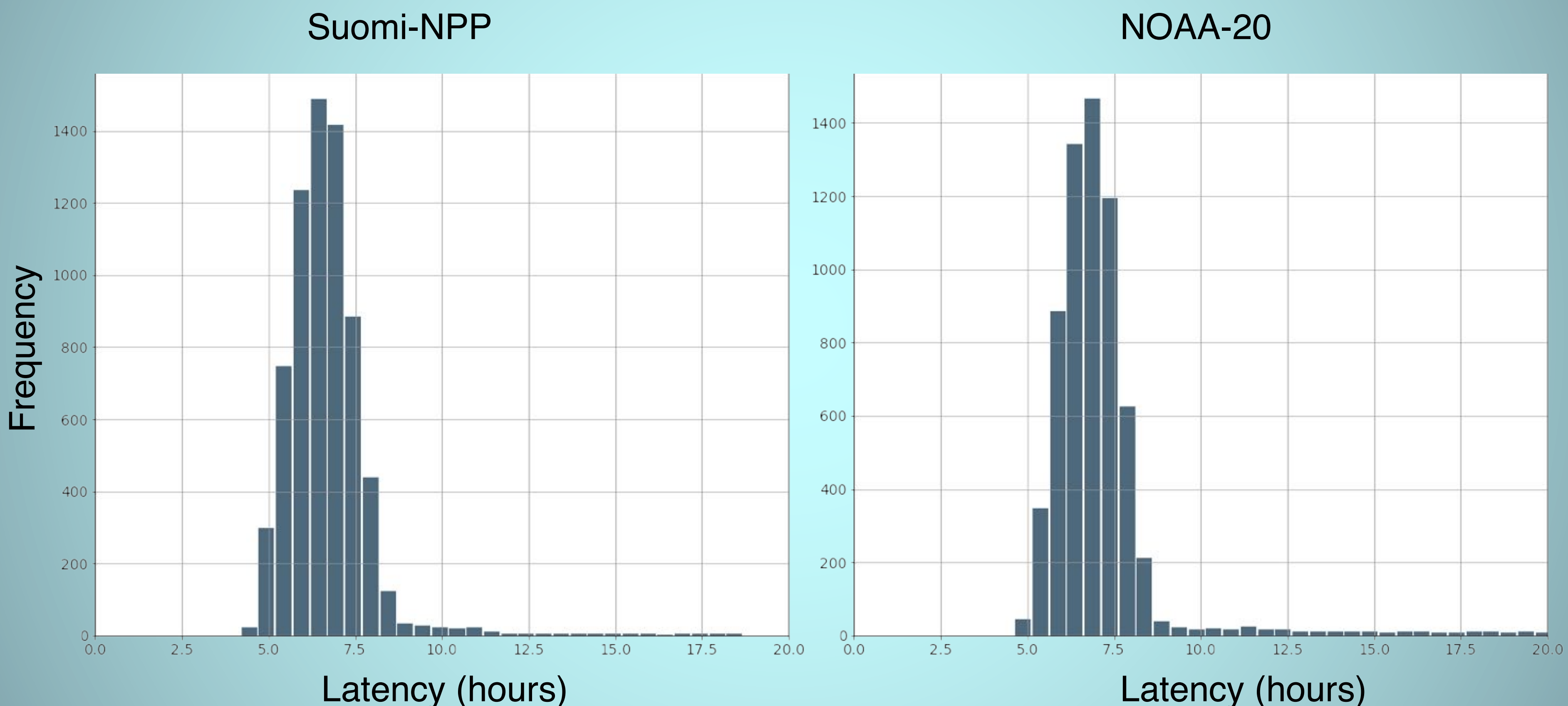
Backup Slides

Full day of MODIS [measured– constructed radiances/BTs] 17 April, 2015

	Full swath (SZA=0°-65°)		Sounder swath (SZA<50°)		Outside sounder swath (>=50°)	
	Mean	RMS	Mean	RMS	Mean	RMS
Band 25	-0.003 -0.320	0.011 1.010	-0.002 -0.179	0.008 0.731	-0.009 -0.856	0.018 1.694
Band 27	0.000 0.033	0.058 1.384	0.003 0.121	0.048 1.117	-0.014 -0.304	0.086 2.109
Band 35	-0.003 -0.049	0.044 0.812	0.003 0.052	0.034 0.614	-0.024 -0.433	0.070 1.314

Upper line (black numbers): radiances (W m^{-2} str^{-1} μm^{-1})
Lower line (green numbers): brightness temperatures (K)

Results are best within the CrIS swath and degrade modestly outside of it.


Suomi-NPP
NOAA-20
Frequency
Latency (hours)
Latency (hours)
0
200
400
600
800
1000
1200
1400
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0